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Title of the Invention

SEMICONDUCTOR INTEGRATED CIRCUIT HAVING  
A SELF-TESTING FUNCTION

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SEMICONDUCTOR INTEGRATED CIRCUIT HAVING  
A SELF-TESTING FUNCTION

BACKGROUND OF THE INVENTION

The present invention relates to a testing technique of semiconductor integrated circuits, and such a technique which is useful for application to communication LSIs.

In tests of semiconductor integrated circuits, there are included a DC (direct current) characteristic test, an AC (alternating current) characteristic test, and a function test. In the DC characteristic test, voltages of external terminals of an LSI and currents flowing through external terminals are measured in a DC manner. In the AC characteristic test, there are included measurements of the propagation delay time between input and output terminals, transition time of output waveforms, setup time, hold time, minimum clock pulse width, and maximum operation frequency. The function test is a test for determining whether the LSI operates without exhibiting an abnormality in its function when prescribed operation conditions are given to the LSI. In this function test, it is determined whether the function of the LSI is good by comparing signals output from the LSI with expected values when a test pattern is input to the LSI. For conducting such a function test, there

are needed a pattern generating circuit for generating  
a test pattern and a comparing circuit for comparing  
signals output from the LSI with expected values. Some  
LSIs incorporate a pattern generating circuit and a  
5 comparing circuit, whereas some LSIs do not incorporate  
a pattern generating circuit and a comparing circuit.  
In the case where a pattern generating circuit and a  
comparing circuit are not incorporated, a pattern  
generating circuit and a comparing circuit disposed  
10 outside the LSI are used.

Furthermore, as described in JP-A-2-19051  
(laid open on January 23, 1990), there is known a modem  
control apparatus having a self test function for  
checking whether the transmission and reception  
15 function is normally performed. This modem control  
apparatus includes switch means for forming a loopback  
path by connecting modem ends of a receiving system  
control section and a transmitting system control  
section to each other when power is turned on, a  
20 pattern generator for supplying pattern data for a  
loopback test to an input side of the receiving system  
control section in synchronism with operation of the  
switch means, and a checker for comparing the pattern  
data output from the pattern generator with a result  
25 looped back via the receiving system control section,  
the switch means and the transmitting system control  
section and conveying a result of the comparison to the  
control sections.

Especially in such an LSI as to conduct multiplexing processing of  $n$  channels as in an LSI for communication, it is necessary to demultiplex a signal output from the pattern generating circuit to  $n$  channels. In this case, therefore, the pattern signal actually generated in the test pattern generating circuit must have a frequency that is  $n$  times the frequency of the test pattern used in the test of the LSI. As the clock frequency of the LSI becomes higher, design of a pattern generating circuit corresponding thereto becomes difficult. In addition, in a judging circuit, which receives a response pattern, signal synchronization is needed in signal comparison. If the frequency of the operation clock becomes high, however, signal synchronization also becomes difficult.

In JP-A-2-19051, detailed configurations in respective blocks are not shown. However, it is necessary to supply a signal generated by the pattern generator to the receiving system control section and supply it to the checker as well, for the purpose of comparing it with an output signal of the transmission system control section.

#### SUMMARY OF THE INVENTION

An object of the present invention is to provide a technique for conducting tests of semiconductor integrated circuits easily and inexpensively.

The above described and other objects and novel features will become apparent from the ensuing description and accompanying drawing.

In accordance with one aspect of the present invention, a semiconductor integrated circuit includes on a single semiconductor chip: a test mode input terminal supplied with a test mode signal; a transmitting circuit having a function of converting first parallel signals for a plurality of channels to a first serial signal; a receiving circuit having a function of converting a second serial signal to second parallel signals for a plurality of channels; a test signal generating circuit responsive to the test mode signal, for generating test parallel signals to be supplied to the transmitting circuit; a first selector for supplying either the test parallel signals or the first parallel signals to the transmitting circuit; a second selector responsive to the test mode signal, for supplying either the first serial signal or the second serial signal to the receiving circuit; and an operation judging circuit responsive to the test mode signal, the operation judging circuit being connected so as to receive response parallel signals from the receiving circuit.

25           The test signal generating circuit includes  
first circuits for generating test parallel signals  
that are equivalent to the first parallel signals for a  
plurality of channels.

The operation judging circuit includes:

second circuits each capable of holding a value of one  
pulse of its associated one of pulse sequences of the  
response parallel signals received from the receiving  
5 circuit; third circuits for generating expected values  
for pulses of pulse sequences in the response parallel  
signals received from the receiving circuit after the  
pulses whose signal values have been held, based on  
signal values held in the second circuit; and fourth  
10 circuits for comparing values of pulses of the pulse  
sequences in the response parallel signals received  
from the receiving circuit with the expected values  
generated by the third circuit.

The test signal generating circuit and the  
15 operation judging circuit may be formed so as to  
operate in accordance with a clock having a frequency  
corresponding to a transfer rate of the first or second  
parallel signals.

#### BRIEF DESCRIPTION OF THE DRAWINGS

20 FIG. 1 is a block diagram showing a  
configuration example of a communication LSI, which is  
an example of a semiconductor integrated circuit  
according to an embodiment of the present invention;

FIG. 2 is a circuit diagram showing a  
25 configuration example of a test signal generation  
circuit that can be used in a communication LSI  
according to an embodiment of the present invention;

FIG. 3 is a circuit diagram showing a configuration example of an operation judging circuit that can be used in a communication LSI according to an embodiment of the present invention;

5           FIG. 4 is a diagram showing conventional LSI tests;

FIG. 5 is a circuit diagram showing a configuration example of a test signal generation circuit shown in FIG. 4; and

10           FIG. 6 is a circuit diagram showing a configuration example of an operation judging circuit shown in FIG. 4.

#### DESCRIPTION OF THE EMBODIMENTS

FIG. 1 shows a communication LSI, which is an example of a semiconductor integrated circuit according to an embodiment of the present invention.

Although not especially limited, a communication LSI 20 shown in FIG. 1 is formed on one semiconductor substrate such as, for example, a single crystal silicon substrate by using a known semiconductor integrated circuit fabrication technique.

Although not especially limited, the communication LSI 20 is incorporated in a transceiver for fast optical communication. The communication LSI 20 includes a transmitting circuit 12 and a receiving circuit 15.

The transmitting circuit 12 has a function of multiplexing transmission side data (first parallel signals) supplied from the outside via  $n$  (where  $n$  is a positive integer) transmission side input terminals T1-1 to T1- $n$ , thereby converting them to a first serial signal, and transmitting the first serial signal. Output data (the first serial signal) from the transmitting circuit 12 is output to the outside via a transmission side output terminal T4.

10           The receiving circuit 15 has a function of converting serial data (a second serial signal) supplied from the outside via a reception side input terminal T5 to parallel data and outputting the parallel data. Output data (second parallel signals) 15 of the receiving circuit 15 are output to the outside via reception side output terminals T2-1 to T2- $n$ .

In the transceiver for fast optical communication, the transmission side output terminal T4 and the reception side input terminal T5 are coupled to 20 a front end, which is not illustrated. The front end includes an optical modulation circuit for modulating laser light on the basis of the output data from the transmission side output terminal T4, and a light receiving element for converting laser light supplied 25 via an optical fiber to an electric signal. An electric signal obtained by the light receiving element is transmitted to the receiving circuit 15 via the reception side input terminal T5. Other multiplexing



circuits (not illustrated) might be coupled to the transmission side input terminals T1-1 to T1-n.

Multiplexed signals from the multiplexing circuits are taken into the chip via the transmission side input

5 terminals T1-1 to T1-n. And other demultiplexing circuits (not illustrated) might be connected to the reception side output terminals T2-1 to T2-n. In those other demultiplexing circuits, each of n output data from the receiving circuit 15 is demultiplexed,  
10 respectively.

A test mode signal input terminal T6 for taking in a test mode signal TEST is provided. In the case where the test mode signal TEST input via the test mode signal input terminal T6 is at a low level, the  
15 communication LSI 20 is in an ordinary operation state. On the other hand, in the case where the test mode signal TEST is at a high level, the communication LSI 20 is in a test mode state.

A circuit configuration that makes the self  
20 test of the communication LSI 20 possible will now be described.

In order to make the self test of the communication LSI 20 possible, selectors 11-1 to 11-n and 14, a test signal generating circuit 13, and an  
25 operation judging circuit 16 (such as a comparing circuit) are provided.

Although not especially limited, the test signal generating circuit 13 generates a random pattern

(test parallel signals) of a PN sequence (PRBS: Pseudo Random Bit Sequence) that is recommended for evaluation in International Telecommunication Union (ITU), ITU-T 0151, 0153, on the basis of a clock signal CLOCK

5 supplied from the transmitting circuit 12.

At this time, in the present embodiment, the frequency of the clock signal CLOCK is a frequency corresponding to the transfer rate of the parallel signals supplied to the transmission side input  
10 terminals T1-1 to T1-n in ordinary operation of the LSI 20, and it is markedly low as compared with the conventional technique.

The selectors 11-1 to 11-n have a function of transferring either data (the first parallel signals)  
15 supplied via the transmission side input terminals T1-1 to T1-n or the test parallel signals supplied from the test signal generating circuit 13 to the transmitting circuit 12 according to the test mode signal TEST.

Although not especially limited, the selectors 11-1 to  
20 11-n transfer data supplied via the transmission side input terminals T1-1 to T1-n to the transmitting circuit 12 when the test mode signal TEST is at a low level, whereas the selectors 11-1 to 11-n transfer the test signal data (test parallel signals) supplied from  
25 the test signal generating circuit 13 to the transmitting circuit 12 when the test mode signal TEST is at a high level.

The selector 14 has a function of transferring either data (the second serial signal) supplied via the reception side data input terminal T5 or the output signal of the transmitting circuit 12 to the receiving circuit 15 according to the test mode signal TEST. Although not especially limited, the selector 14 transfers data (the second serial signal) supplied via the reception side data input terminal T5 to the receiving circuit 15 when the test mode signal TEST is at a low level, whereas the selector 14 transfers the output data supplied from the transmitting circuit 12 to the receiving circuit 15 when the test mode signal TEST is at a high level.

The operation judging circuit 16 has a function of judging whether the LSI 20 is operating normally on the basis of response parallel signals output from the receiving circuit 15. This judging is executed by using the clock signal CLOCK transferred from the receiving circuit 15. A result of judging in the operation judging circuit 16 is output to the outside via a test result output terminal T3.

Details of respective components will now be described.

FIG. 2 shows a configuration example of the test signal generating circuit 13.

Although not especially limited, the test signal generating circuit 13 has a configuration of thirty-one stages of a PN sequence. The test signal

generating circuit 13 is formed by coupling thirty-one flip-flop circuits 201 to 231 and 16 exclusive-OR circuits 241 to 255. Test data (the test parallel signals) Dout01 to Dout16 in a parallel form are  
5 obtained from the flip-flop circuits 216 to 231. The flip-flop circuits 201 to 215 are disposed in a stage preceding the stage of the flip-flop circuits 216 to 230. Output signals of the flip-flop circuits 201 to 215 are taken in by the flip-flop circuits 216 to 130  
10 of the subsequent stage.

An exclusive OR circuit 241 performs an exclusive OR-ing function on the test data Dout02 and the test data Dout05, and supplies a result thereof to the flip-flop circuit 201 located in the subsequent  
15 stage. An exclusive OR circuit 242 performs an exclusive OR-ing function on the test data Dout03 and the test data Dout06, and supplies a result thereof to the flip-flop circuit 202 located in the subsequent stage. An exclusive OR circuit 243 performs an  
20 exclusive OR-ing function on the test data Dout04 and the test data Dout07, and supplies a result thereof to the flip-flop circuit 203 located in the subsequent stage. An exclusive OR circuit 244 performs an exclusive OR-ing function on the test data Dout05 and  
25 the test data Dout08, and supplies a result thereof to the flip-flop circuit 204 located in the subsequent stage. An exclusive OR circuit 245 performs an exclusive OR-ing function on the test data Dout06 and

the test data Dout09, and supplies a result thereof to the flip-flop circuit 205 located in the subsequent stage. An exclusive OR circuit 246 performs an exclusive OR-ing function on the test data Dout07 and the test data Dout10, and supplies a result thereof to the flip-flop circuit 206 located in the subsequent stage. An exclusive OR circuit 247 performs an exclusive OR-ing function on the test data Dout08 and the test data Dout11, and supplies a result thereof to the flip-flop circuit 207 located in the subsequent stage. An exclusive OR circuit 248 performs an exclusive OR-ing function on the test data Dout09 and the test data Dout12, and supplies a result thereof to the flip-flop circuit 208 located in the subsequent stage. An exclusive OR circuit 249 performs an exclusive OR-ing function on the test data Dout10 and the test data Dout13, and supplies a result thereof to the flip-flop circuit 209 located in the subsequent stage. An exclusive OR circuit 250 performs an exclusive OR-ing function on the test data Dout11 and the test data Dout14, and supplies a result thereof to the flip-flop circuit 210 located in the subsequent stage. An exclusive OR circuit 251 performs an exclusive OR-ing function on the test data Dout12 and the test data Dout15, and supplies a result thereof to the flip-flop circuit 211 located in the subsequent stage. An exclusive OR circuit 252 performs an exclusive OR-ing function on the test data Dout13 and

the test data Dout16, and supplies a result thereof to the flip-flop circuit 212 located in the subsequent stage. An exclusive OR circuit 253 performs an exclusive OR-ing function on the test data Dout14 and test data from the flip-flop circuit 201, and supplies a result thereof to the flip-flop circuit 213 located in the subsequent stage. An exclusive OR circuit 254 performs an exclusive OR-ing function on the test data Dout15 and test data from the flip-flop circuit 202, and supplies a result thereof to the flip-flop circuit 214 located in the subsequent stage. An exclusive OR circuit 255 performs an exclusive OR-ing function on the test data Dout16 and test data from the flip-flop circuit 203, and supplies a result thereof to the flip-flop circuit 215 located in the subsequent stage. An exclusive OR circuit 256 performs an exclusive OR-ing function on the test data Dout01 and the test data Dout04, and supplies a result thereof to the flip-flop circuit 231 located in the subsequent stage.

The flip-flop circuits 201 to 215 and 216 to 231 operate in synchronism with the clock signal CLOCK. The flip-flop circuits 201 to 215 and 216 to 231 are in the reset state when the test mode signal TEST is at a low level. When the test mode signal TEST is at a high level, the reset state is canceled and a test pattern is generated. By this reset, the flip-flop circuits 201 to 215 and 216 to 231 are made to have a logic 1 as the initial value.

Here, the flip-flop circuits 201 to 231 and the exclusive OR circuits 241 to 256 are shown as an example of a first circuit in the present embodiment. As described above, the test signal generating circuit 13 operates in accordance with the clock signal CLK supplied from the transmitting circuit 12. The frequency of clock signal CLK is a frequency corresponding to the transfer rate of the parallel signals supplied to the transmission side input terminals, and it is markedly lower as compared with the conventional technique.

FIG. 3 shows a configuration example of the operation judging circuit 16.

There are provided flip-flop circuits 301 to 316 for taking in the response data (the response parallel signals) Din01 to Din16 transferred from the receiving circuit 15. In a stage subsequent to the flip-flop circuits 302 to 316, there are disposed flip-flop circuits 317 to 331, to which output signals of the flip-flop circuits 302 to 316 are transferred. The flip-flop circuits 301 to 331 correspond to the flip-flop circuits 201 to 231 (see FIG. 2) included in the test signal generating circuit 13. The exclusive OR circuits 341 to 356 correspond to the exclusive OR circuits 241 to 256 (see FIG. 2) included in the test signal generating circuit 13.

An exclusive OR circuit 341 performs an exclusive OR-ing function on an output signal of the

flip-flop circuit 317 and an output signal of the flip-flop circuit 320, and supplies a result thereof to an exclusive NOR circuit 361 located in a subsequent stage. An exclusive OR circuit 342 performs an

5 exclusive OR-ing function on an output signal of the flip-flop circuit 318 and an output signal of the flip-flop circuit 321, and supplies a result thereof to an exclusive NOR circuit 362 located in a subsequent stage. An exclusive OR circuit 343 performs an

10 exclusive OR-ing function on an output signal of the flip-flop circuit 319 and an output signal of the flip-flop circuit 322, and supplies a result thereof to an exclusive NOR circuit 363 located in the subsequent stage. An exclusive OR circuit 344 performs an

15 exclusive OR-ing function on an output signal of the flip-flop circuit 320 and an output signal of the flip-flop circuit 323, and supplies a result thereof to an exclusive NOR circuit 364 located in the subsequent stage. An exclusive OR circuit 345 performs an

20 exclusive OR-ing function on an output signal of the flip-flop circuit 321 and an output signal of the flip-flop circuit 324, and supplies a result thereof to an exclusive NOR circuit 365 located in the subsequent stage. An exclusive OR circuit 346 performs an

25 exclusive OR-ing function on an output signal of the flip-flop circuit 322 and an output signal of the flip-flop circuit 325, and supplies a result thereof to an exclusive NOR circuit 366 located in the subsequent

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stage. An exclusive OR circuit 347 performs an exclusive OR-ing function on an output signal of the flip-flop circuit 323 and an output signal of the flip-flop circuit 326, and supplies a result thereof to an  
5 exclusive NOR circuit 367 located in the subsequent stage. An exclusive OR circuit 348 performs an exclusive OR-ing function on an output signal of the flip-flop circuit 324 and an output signal of the flip-flop circuit 327, and supplies a result thereof to an  
10 exclusive NOR circuit 368 located in the subsequent stage. An exclusive OR circuit 349 performs an exclusive OR-ing function on an output signal of the flip-flop circuit 325 and an output signal of the flip-flop circuit 328, and supplies a result thereof to an  
15 exclusive NOR circuit 369 located in the subsequent stage. An exclusive OR circuit 350 performs an exclusive OR-ing function on an output signal of the flip-flop circuit 326 and an output signal of the flip-flop circuit 329, and supplies a result thereof to an  
20 exclusive NOR circuit 370 located in the subsequent stage. An exclusive OR circuit 351 performs an exclusive OR-ing function on an output signal of the flip-flop circuit 327 and an output signal of the flip-flop circuit 330, and supplies a result thereof to an  
25 exclusive NOR circuit 371 located in the subsequent stage. An exclusive OR circuit 352 performs an exclusive OR-ing function on an output signal of the flip-flop circuit 328 and an output signal of the flip-

flop circuit 331, and supplies a result thereof to an exclusive NOR circuit 372 located in the subsequent stage. An exclusive OR circuit 353 performs an exclusive OR-ing function on an output signal of the flip-flop circuit 329 and an output signal of the flip-flop circuit 301, and supplies a result thereof to an exclusive NOR circuit 373 located in the subsequent stage. An exclusive OR circuit 354 performs an exclusive OR-ing function on an output signal of the flip-flop circuit 330 and an output signal of the flip-flop circuit 302, and supplies a result thereof to an exclusive NOR circuit 374 located in the subsequent stage. An exclusive OR circuit 355 performs an exclusive OR-ing function on an output signal of the flip-flop circuit 331 and an output signal of the flip-flop circuit 303, and supplies a result thereof to an exclusive NOR circuit 375 located in the subsequent stage. An exclusive OR circuit 356 performs an exclusive OR-ing function on an output signal of the flip-flop circuit 301 and an output signal of the flip-flop circuit 304, and supplies a result thereof to an exclusive NOR circuit 376 located in the subsequent stage. An exclusive NOR circuit 361 performs an exclusive NOR-ing function on the newly input response data Din01 and the output signal of the exclusive OR circuit 341, and supplies a result thereof to an AND circuit 381 located in a subsequent stage. An exclusive NOR circuit 362 performs an exclusive NOR-ing

function on the newly input response data Din02 and the output signal of the exclusive OR circuit 342, and supplies a result thereof to the AND circuit 381 located in the subsequent stage. An exclusive NOR

5 circuit 363 performs an exclusive NOR-ing function on the newly input response data Din03 and the output signal of the exclusive OR circuit 343, and supplies a result thereof to the AND circuit 381 located in the subsequent stage. An exclusive NOR circuit 364

10 performs an exclusive NOR-ing function on the newly input response data Din04 and the output signal of the exclusive OR circuit 344, and supplies a result thereof to the AND circuit 381 located in the subsequent stage. An exclusive NOR circuit 365 performs an exclusive NOR-

15 ing function on the newly input response data Din05 and the output signal of the exclusive OR circuit 345, and supplies a result thereof to the AND circuit 381 located in the subsequent stage. An exclusive NOR circuit 366 performs an exclusive NOR-ing function on

20 the newly input response data Din06 and the output signal of the exclusive OR circuit 346, and supplies a result thereof to the AND circuit 381 located in the subsequent stage. An exclusive NOR circuit 367

25 performs an exclusive NOR-ing function on the newly input response data Din07 and the output signal of the exclusive OR circuit 347, and supplies a result thereof to the AND circuit 381 located in the subsequent stage.

5 located in the subsequent stage. An exclusive NOR circuit 369 performs an exclusive NOR-ing function on the newly input response data Din09 and the output signal of the exclusive OR circuit 349, and supplies a result thereof to the AND circuit 381 located in the

15 An exclusive NOR circuit 371 performs an exclusive NOR-  
ing function on the newly input response data Din11 and  
the output signal of the exclusive OR circuit 351, and  
supplies a result thereof to the AND circuit 381  
located in the subsequent stage. An exclusive NOR

25 performs an exclusive NOR-ing function on the newly  
input response data Din13 and the output signal of the  
exclusive OR circuit 353, and supplies a result thereof  
to the AND circuit 381 located in the subsequent stage.

5 located in the subsequent stage. An exclusive NOR  
circuit 375 performs an exclusive NOR-ing function on  
the newly input response data Din15 and the output  
signal of the exclusive OR circuit 355, and supplies a  
result thereof to the AND circuit 381 located in the  
10 subsequent stage. An exclusive NOR circuit 376  
performs an exclusive NOR-ing function on the newly  
input response data Din16 and the output signal of the  
exclusive OR circuit 356, and supplies a result thereof  
to the AND circuit 381 located in the subsequent stage.

The frequency of clock signal CLK is a  
25 frequency corresponding to the transfer rate of the  
parallel signals supplied from the receiving circuit 15  
to the reception side output terminals T2-1 to T2-n.  
Therefore, the operation judging circuit 16 operates

with a clock signal having a frequency that is markedly lower as compared with the conventional technique.

5 Data held by the flip-flop circuits 301 to 331 (previously input data) are subject to logic operation in the exclusive OR circuits 341 to 356. Data equivalent to the test data Dout01 to Dout16 currently output from the test signal generating circuit 13 are obtained in outputs of the exclusive OR circuits 341 to 356. These data become expected values  
10 of pattern data output from the receiving circuit 15 in the case where predetermined random pattern data from the test signal generating circuit 13 are supplied to the transmitting circuit 12. Matching decision between the test pattern and the response pattern is conducted  
15 by comparing these with the response data Din01 to Din16 in the exclusive NOR circuits 361 to 376. If all bits of the response data Din01 to Din16 coincide with the corresponding expected values (output signals of the exclusive OR circuits 341 to 356), then all of  
20 outputs of the exclusive NOR circuits 361 to 376 become high levels and consequently the output of the AND circuit 381 becomes a high logic level.

On the other hand, if the input data Din01 to Din16 do not coincide with the expected values (output  
25 signals of the exclusive OR circuits 341 to 356) even in one bit, then it means a failure of the transmitting circuit 12 or the receiving circuit 15. In this case, all output signals of the exclusive NOR circuits 361 to

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376 do not become high levels, and the output terminal of the AND circuit 381 becomes a low level. As a result, an SR latch circuit 384 is set and the SR latch circuit 384 is fixed to a low level in its output  
5 signal. The fact that the output signal of the SR latch circuit has been fixed to the low level is conveyed to an external output or a host system via a signal transfer path, which is not illustrated. Once the SR latch circuit 384 is set, the output logic level  
10 is fixed unless the SR latch circuit 384 is reset by a reset circuit 383. Even if the output signal of the AND circuit 381 becomes the high level thereafter, therefore, the output logic level is not changed thereby.

15 If the test mode signal TEST is at the low level, then the reset circuit 383 resets the SR latch circuit 384. After a predetermined time has elapsed since transition of the test mode signal TEST from the low level to the high level, the reset signal of the SR  
20 latch circuit 384 is changed from the low level to the high level and thereby the reset state of the SR latch circuit 384 is canceled. The reason why the reset cancel of the SR latch circuit 384 is thus delayed will now be described.

25 Immediately after the test mode signal TEST is changed from the low level to the high level, the circuit operation is unstable. After logic levels of the flip-flop circuits 301 to 331, the exclusive OR

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circuits 341 to 356, the exclusive OR circuits 361 to 376, and the AND circuit 381 have been established, therefore, the reset state of the SR latch circuit 384 is canceled. It is thus prevented that the SR latch  
5 circuit 384 is set by an undesired signal. That is the reason.

Here, the flip-flop circuits 301 to 331 exemplify second circuits in the present embodiment. The exclusive OR circuits 341 to 356 exemplify third  
10 circuits in the present embodiment. The exclusive NOR circuits 361 to 376 exemplify fourth circuits in the present embodiment.

FIG. 4 shows a circuit to be compared with the communication LSI 20.

15 A communication LSI 40 shown in FIG. 4 differs remarkably from the communication LSI 20 shown in FIG. 1 in that the test signal generating circuit 13, the selectors 11-1 to 11-n, and the operation judging circuit 16 are not incorporated. When testing  
20 the communication LSI 40, therefore, test signal generating apparatuses 41 and 43 and operation judging apparatuses 42 and 44 are coupled to the communication LSI. Test pattern (random pattern) data generated by the test signal generating apparatus 41 are transferred  
25 to a transmitting circuit 12' via transmission side input terminals T1-1' to T1-n'. In that case, pattern data output from the transmitting circuit 12' are supplied to the operation judging apparatus 42 via a



transmission side output terminal T4', and compared  
with expected values therein. Matching decision of the  
pattern data is thus conducted. In the same way, test  
pattern (random pattern) data generated by the test  
5 signal generating apparatus 43 are transferred to a  
receiving circuit 15' via reception side input terminal  
T5'. In that case, pattern data output from the  
receiving circuit 15' are supplied to the operation  
judging apparatus 44 via reception side output  
10 terminals T2-1' to T2-n', and compared with expected  
values therein. Matching decision of the pattern data  
is thus conducted.

FIG. 5 shows a configuration example of the  
test signal generating apparatus 41.

15 The test signal generating apparatus 41  
generates a test pattern of thirty-one stages of PN.  
As shown in FIG. 5, the test signal generating  
apparatus 41 is formed by coupling thirty-one flip-flop  
circuits 501 to 531, an exclusive OR circuit 540 and a  
20 multiplexer 541. The thirty-one flip-flop circuits 501  
to 531 are connected in series. The exclusive OR  
circuit 540 performs an exclusive OR-ing function on  
output signals of the flip-flop circuit 528 and the  
flip-flop circuit 531. Its result is transferred to an  
25 input terminal of the flip-flop circuit 501. The flip-  
flop circuits 501 to 531 operate in synchronism with a  
clock signal CLOCK. The flip-flop circuits 501 to 531  
are reset by a reset signal RESET. By this reset, the

flip-flop circuits 501 to 531 are made to have a logic 1 as the initial value. The transmitting circuit 12' has a plurality of input channels. Therefore, the output signal of the flip-flop circuit 531 is transferred to the demultiplexer 541 of the subsequent stage, and demultiplexed at a ratio of 1:n therein. Thus, test pattern data of a parallel form are obtained. The test pattern data are transferred to the transmitting circuit 12'. Since demultiplexing is conducted at a ratio of 1:n, it is necessary to generate the PN pattern with a frequency that is n times that of the test pattern. For example, in the case where such a frequency as to exceed 100 MHz is used in the semiconductor integrated circuit 20, the circuit design becomes difficult.

FIG. 6 shows a configuration example of the operation judging apparatus 44.

The operation judging apparatus 44 is formed by coupling thirty-one flip-flop circuits 601 to 631, a multiplexer 641, a synchronizing circuit 642, and exclusive OR circuit 643 and 644. The exclusive OR circuit 643 performs an exclusive OR-ing function on output signals of the flip-flop circuit 628 and the flip-flop circuit 631. A result thereof is transferred to the flip-flop circuit 601. A Signals output from the receiving circuit 15 are supplied to the multiplexer 641 and converted to a serial form with a ratio of n:1. An output signal of the multiplexer 641

and the output signal of the flip-flop circuit 631 are compared with each other by the exclusive OR circuit 644. A result of this comparison is output as a matching decision result. In the logical comparison conducted in the exclusive OR circuit 644, the output signal of the flip-flop circuit 631 needs to be synchronized to the output signal of the multiplexer 641. Therefore, the synchronizing circuit 642 for synchronizing the output signal of the flip-flop circuit 631 with the output signal of the multiplexer 641 is indispensable. However, it is necessary to make the operation judging apparatus operate at a frequency which is n times that of the semiconductor integrated circuit 40. In such a case, especially design of the synchronizing circuit becomes difficult.

On the other hand, the communication LSI 20 shown in FIG.1 brings about the following operational effects.

(1) Since the test signal generating circuit 13 and the operation judging circuit 16 are incorporated in the semiconductor integrated circuit, it becomes unnecessary to prepare the test signal generating circuit 13 and the operation judging circuit 16 outside the chip. As a result, the manufacturing cost of the communication LSI can be reduced. Furthermore, the test signal generating circuit 13 is formed so as to include the first circuits for generating a predetermined random pattern, and the

output terminals that are pulled out from the first  
circuits and that are capable of outputting the test  
parallel signals in such a state that the random  
pattern is divided into n parts. Accordingly, the test  
5 pattern generated by the test signal generating circuit  
13 can be supplied to the transmitting circuit 12 in  
the parallel form. Therefore, it becomes unnecessary  
to demultiplex the signal output from the test signal  
generating circuit 13 to n channels. As a result, the  
10 frequency of the test signal actually generated in the  
test signal generating circuit 13 may be the frequency  
of the test pattern needed in the test of the  
semiconductor integrated circuit 20. It is thus  
unnecessary to generate the test signal at a frequency  
15 of n times by considering the pattern data  
demultiplexing conducted by the demultiplexer.  
Therefore, the circuit design and, in addition, the  
test of the semiconductor integrated circuit can be  
facilitated.

20 (2) In the test signal generating circuit,  
there are provided a plurality of flip-flop circuits  
216 to 231 corresponding to the test parallel signals,  
a plurality of flip-flop circuits 201 to 215 disposed  
in a stage preceding that of the flip-flop circuits 216  
25 to 231, and exclusive OR circuits 241 to 256 each for  
comparing logic values of two bits located at a  
distance of, for example, three bits between and  
included in the test parallel signals supplied from a

plurality of flip-flop circuits 216 to 231 and  
supplying results of the comparison to corresponding  
flip-flop circuits 201 to 215 and 231. As a result, a  
random pattern of a plurality of channels corresponding  
5 to the parallel signals can be generated easily.

(3) In the operation judging circuit 16,  
there is provided the AND circuit 381 for performing an  
AND-ing function on a plurality of output signals of  
the exclusive NOR circuits 361 to 376. As a result,  
10 the number of bits of the test pattern matching  
decision result can be reduced.

(4) In the operation judging circuit 16,  
there are provided the flip-flop circuit 382 for taking  
in the output signal of the AND circuit 381 in  
15 synchronism with a clock signal supplied from the  
receiving circuit; and the SR latch circuit 384 that is  
set by the output signal of the flip-flop circuit 382.  
After the SR latch circuit 384 is set by the output  
signal of the flip-flop circuit 382, the result of  
20 matching decision between the test pattern and the  
response pattern can be prevented from being destroyed  
by a signal output by the flip-flop circuit 382  
thereafter.

(5) In the operation judging circuit 16,  
25 there is provided a reset circuit 383 capable of  
canceling the reset state of the SR latch circuit 384  
upon elapse of a predetermined time after the circuit  
disposed in the stage preceding that of the SR latch

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circuit 384 is reset. As a result, an undesired logic signal can be prevented from being held in the SR latch circuit 384.

(6) In the operation judging circuit 16, the expected values can be obtained on the basis of the output signals of the receiving circuit 15. Therefore, it is not necessary to take the test pattern signal generated by the test signal generating circuit 13 into the operation judging circuit 16 as the expected values. As a result, a signal transfer path for supplying the test pattern signal from the test signal generating circuit 13 to the operation judging circuit 16 becomes unnecessary. In addition, in the signal comparison in the operation judging circuit 16, it is not necessary to synchronize the signal with respect to the test signal generating circuit 13.

Heretofore, the invention made by the present inventors has been described concretely. However, the present invention is not limited thereto, but it is a matter of course that various modifications can be made without departing from the spirit of the invention.

For example, in the above described example, a test pattern of thirty-one stages of PN is generated. However, the test pattern is not limited thereto, but it can be change to, for example, twenty-three stages of PN.

Heretofore, the case where the invention made by the present inventors is applied to a communication

LSI which is a field of its background utilization has been described. However, the present invention is not limited thereto, but the present invention can be applied widely to various semiconductor integrated  
5 circuits.

The present invention can be applied under the condition that at least a logic circuit is included.

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